THE IMPACT OF OCULAR PRESSURES, MATERIAL PROPERTIES AND GEOMETRY ON OPTIC NERVE HEAD DEFORMATION

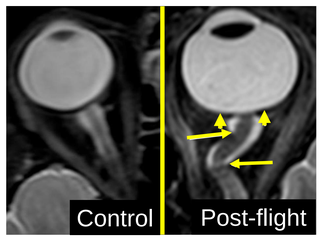
Andrew J. Feola[1] , Jerry G. Myers[2] , Julia Raykin[1] , Emily S. Nelson[2] , Brian C. Samuels[3], C. Ross Ethier[1]

[1] Wallace H. Coulter Department of Biomedical Engineering, Georgia Institute of Technology and Emory University,

[2] NASA Glenn Research Center, Cleveland, Ohio, United States, [3] Ophthalmology, UAB, Birmingham, Alabama, United States

Background and Purpose

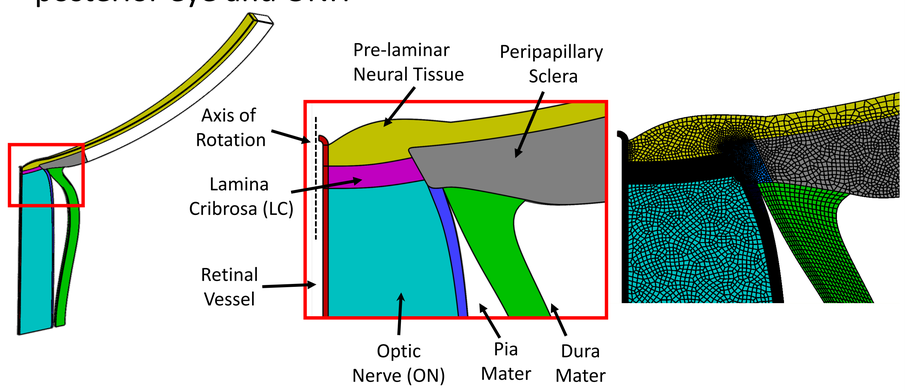
- Elevated intracranial pressure (ICP) is involved/implicated in several ocular conditions: papilledema, glaucoma and Visual Impairment and Intracranial Pressure (VIIP) syndrome
- ICP affects optic nerve head (ONH) biomechanics
- There are likely important inter-individual differences in biomechanical response to ICP, e.g. due to differences in ONH tissue properties.
- **Goal: To develop a finite element (FE) model to simulate how inter-individual differences in pressures, tissue material properties and ocular geometry affect the deformation of ONH tissues.**



Pre- (left) and Post- (right) flight MR scans of an astronaut with VIIP (Kramer et al. 2012). 'The arrows highlight kinking of the optic nerve and the arrowheads indicate posterior globe flattening

Methods: Finite Element Model

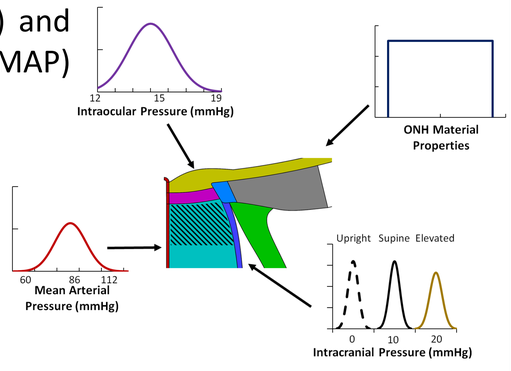
- Extend Sigal et al.'s (IOVS, 2005) geometric model of the posterior eye and ONH



- Tissue material properties: taken from literature and/or estimates.

Methods: Latin Hypercube Sampling

- Simulate a **virtual population**: to account for inter-individual variations in pressures and tissue mechanical properties
- Intraocular pressure (IOP) and mean arterial pressure (MAP) values measured in-flight.
- Three different ICP conditions considered: upright on earth (upright), supine on earth (supine) and microgravity (elevated).

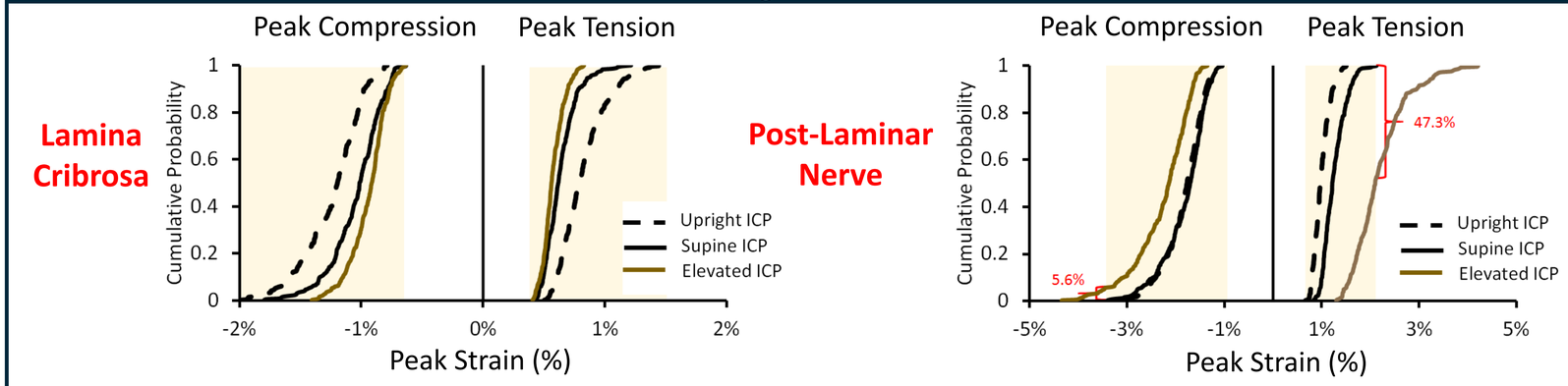


- Assess how changes in several ocular geometric parameters influenced strain distributions under elevated ICP conditions (Table)

	Baseline	Low	High
Scleral Radius (mm)	12	9.6	14.4
Scleral Thickness (mm)	0.8	0.64	0.96
Pia Thickness (mm)	0.06	0.048	0.072

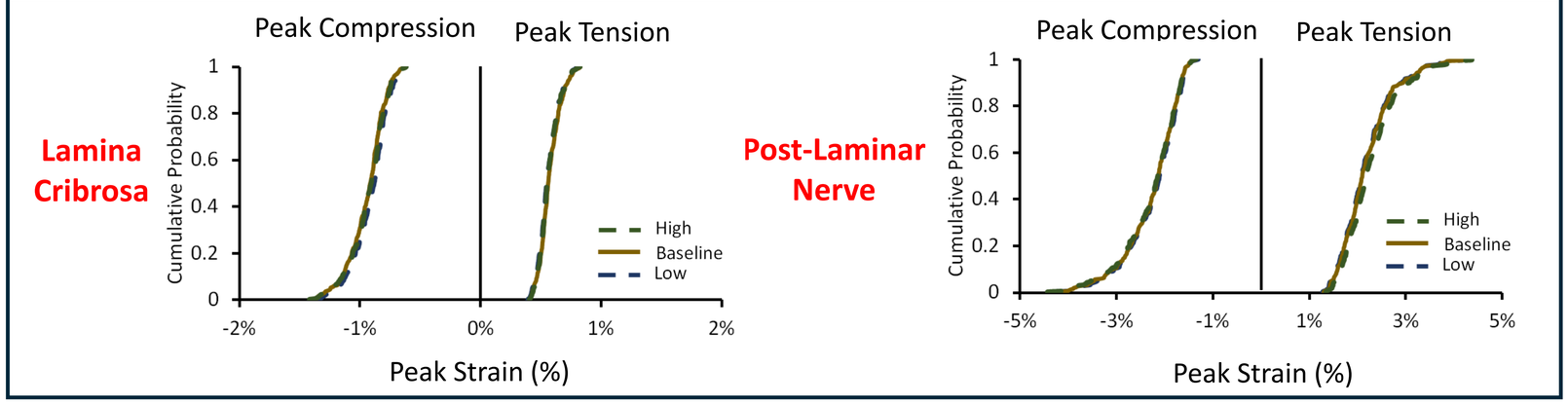
- **Primary outcome measures:** Peak tensile and compressive strains in the LC and post-laminar optic nerve (shaded region)

Effect of Elevating ICP on ONH Strains

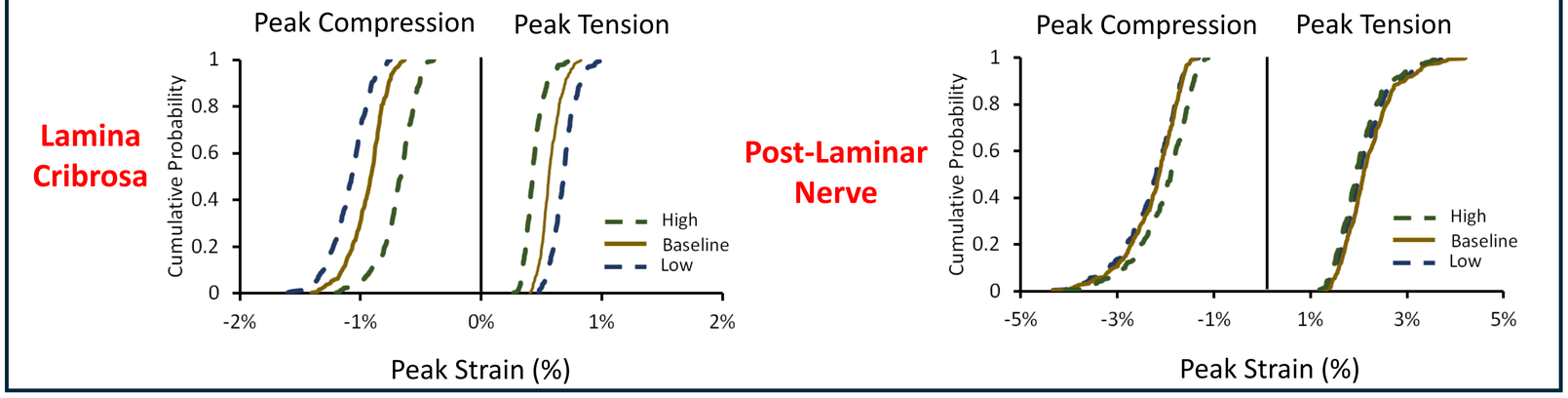


- Shaded region indicate peak tension and compression predicted to occur under terrestrial ICP conditions (upright & supine)

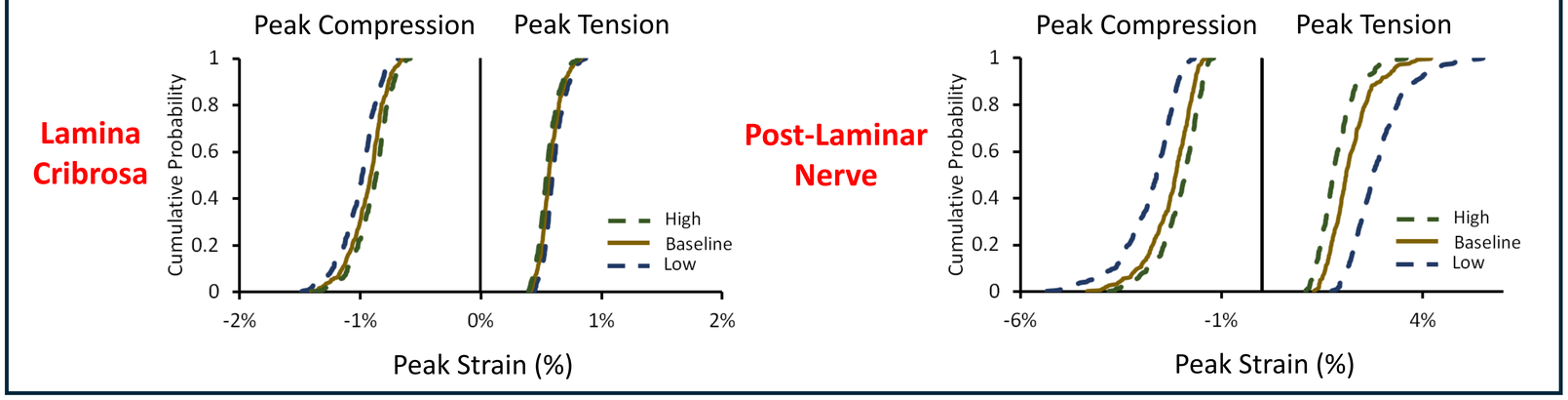
Effect of Varying Sclera Radius on ONH Strains at Elevated ICP



Effect of Varying Sclera Thickness on ONH Strains at Elevated ICP



Effect of Varying Pia Mater Thickness on ONH Strains at Elevated ICP



Summary and Conclusions

- 47% of individuals experience "extreme strains" in the optic nerve with elevated ICP
  - c.f. 41% of astronauts suffering from VIIP syndrome
- Scleral and pia thickness influenced the peak strains in the lamina cribrosa and post-laminar neural tissue, respectively.
- Future computational work should examine how additional or multiple geometric variations influence extreme strains under elevated ICP conditions

Acknowledgements

- NASA
- Georgia Research Alliance